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ABSTRACT

The authors of this curriculum supplement believe in a laboratory approach to chemistry and express the feeling that environmental chemistry provides the students an opportunity to apply theoretical chemistry to important practical problems. There are eighteen activities presented, each accompanied with behavioral objectives, one or more suggested methods of procedure, an introduction giving pertinent facts related to the concept being studied, and the materials needed. In some instances there is a suggested Follow Up Teacher Demonstration. A set of environmental chemical equations is included as well as a detailed table. Selected Environmental Pollutants, taken from the United Nations Conference on the Human Environment. The reference list suggests seven publications regarded as being pertinent and useful to any chemistry teacher involved with environmental chemistry. (EB)

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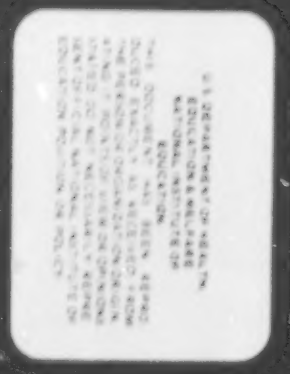

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ACTIVITIES FOR ENVIRONMENTAL CHEMISTRY

Developed Under Provisions of

ESEA, TITLE III ENVIRONMENTAL EDUCATION PROGRAM

Department of Elementary and Secondary Education

Division of Curriculum and Instruction

Milwaukee Public Schools

1972

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RATIONALE

We must have individuals in our society who understand the technical aspects of our environmental problems. Meeting this need is facilitated by teaching environmental chemistry. Environmental chemistry provides an opportunity to apply theoretical chemistry to important practical problems. The writers of this curriculum supplement believe in a laboratory approach to chemistry, where students engage in individual or small group experimentation. This should be supplemented by a variety of teaching methods.

The Authors

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*These are library research activities. All other activities are performed in the laboratory.

SOME IMPORTANT POINTS ABOUT ENVIRONMENTAL POLLUTION

A. Everyone is a victim of, and a contributor to, pollution problems.

B. Most water pollution results from four factors:

1. Sewage
2. Industrial waste
3. Fertilizers
4. Pesticides

C. The major water contaminants are:

1. B.O.D.
2. Organic Chemicals
3. Suspended solids
4. Nitrogen
5. Phosphorous
6. Acids
7. Minerals
8. D.D.T
9. Mercury

D. Most air pollution results from three factors:

1. Automobiles
2. Power Plants
3. Industry

E. The major air contaminants are:

1. Sulfur oxides
2. Particulates
3. Carbon monoxide
4. Nitrogen oxides
5. Hydrocarbons
6. Oxidants
7. Carbon dioxide
8. Asbestos

F. The internal combustion engine is the best air polluting machine yet invented.

G. Air and water contaminants have few geographical boundaries.

H. The effects of repeated or continuous sub-lethal dosages of air and water contaminants are not known.

I. Some contaminants exhibit a synergistic effect in that their combination produces completely unpredicted results.

J. The total cost of environmental pollutants to each individual is probably high.

K. Although the United States contains only 6% of the world population, it uses about 50% of the world's natural resources.

1. The preservation and enhancement of our environment will depend on an informed citizenry which has reevaluated and readjusted its attitude toward the environment.

ACTIVITY #1

PARTICULATES IN AIR-QUANTITATIVE ANALYSIS (FOUR METHODS)

OBJECTIVES:

1. The student will correlate particulate matter in air with sources of pollution.
2. The student will acquire skill in the manipulation of laboratory apparatus.
3. The student will compare locations in the city to amounts of particulate matter.
4. The student will experience team-work in investigating environmental problems.

METHOD 1

INTRODUCTION:

An adequate supply of clean air is essential for life. Of all the pollutants in the air, particulate matter is the most widespread. Particulate matter may originate from many sources such as the internal combustion engine, industry, and wind. We usually recognize particulate matter as haze in the air or soot. Burning eyes, sore throats, and respiratory congestion are frequently the result of particulate air pollution. Particulate matter amounts to about 140,000,000 tons of polluting materials in the air each year. Sunlight falling upon the earth may be reduced by particulate matter by as much a 40%. This reduction adversely affects the photosynthetic process upon which all life depends.

MATERIALS:

1. Large jars
2. Screening
3. Filter paper
4. Funnel
5. Balance

PROCEDURE:

1. Fill jars ¾ full with water.
2. Crimp screening over jar mouth.
3. Place jars in areas to be tested and label each jar as to area.
4. Collect jars at 2 to 4 week intervals.
5. Swirl jars gently and record turbidity.
6. Filter and wash all jar contents into a weighed filter paper.
7. Air dry filter paper and weigh.
8. Subtract to find the weight of particulate water.

PROCESSING THE DATA:

1. Organize the data in chart form:

Area	Visual Comparison	Weight

2. Using a city map, note the amount of pollution at the various areas of collection.
3. How could you account for the differences in pollution at the various locations in the city?
4. Suggest methods by which particulate pollution may be reduced.

METHOD 2

INTRODUCTION:

This is a simplified method for sampling airborn solids in a student's home or neighborhood. This experiment is presented as group or class activity, but can be easily adapted to an individual project.

PROCEDURE:

1. Cut cardboard into approximately 1 inch by 3 inch strips.
2. Punch 3 to 5 holes on one side of the cardboard.
3. Fold the other side over to cover the holes.
4. Place cellophane tape over the holes. (The tape may be lapped over the ends of the cardboard to hold the cover flap down.)
5. Each student should take 3 of these samplers home and place them in areas agreed upon by the class.
6. The samplers should be opened and exposed for exactly 4 hours in the afternoon or evening.
7. After 4 hours, recover the holes with the cover flap.
8. Students should record time and location of sampling on the cover flap with notation of any special conditions.
9. The next day, open the samples in the classroom and count the number of particles in each hole as follows: place the sample on a piece of white paper and count the number. If a hand lens or dissecting microscope is available, use it for a more precise count.

PROCESSING THE DATA:

1. Average your data (particles/hole) for each specific location.
2. Place your averaged data on a map of the neighborhood.
3. Explain why there is greater particulate fallout in some areas than in others.
4. How small do you think the particles can be?
5. How is this experiment related to the increasing incidence of emphysema?

METHOD 3

INTRODUCTION:

Quantitative analysis is finding how much of one or more constituents is present in a given amount of substance. Quantitative data are essential if numerical comparisons of air pollution are to be made between your results and results of other investigators in the world. For this experiment we will determine the number of milligrams of particulate matter per liter of outside air. One method for measuring the amount of air being sampled is to draw air through a calibrated vacuum pump for a specific period of time. If your vacuum pump is not calibrated, a procedure for doing this is given at the end of the experiment. If an air flow meter is available, it can be inserted in the vacuum line, and the pump need not be calibrated.

MATERIALS:

1. Vacuum pump
2. Buchner funnel
3. Filter paper
4. Balance
5. Rubber tubing
6. Air flow meter, if available

PROCEDURE:

1. Connect the Buchner funnel directly to the inlet of the vacuum pump, using rubber tubing.
2. Place a weighed filter paper in the Buchner funnel.
3. Run pump for a 24-hour period of time.
4. Weigh filter paper.
5. If there is no measurable increase in weight, continue process for additional 24-hour periods.

PROCESSING THE DATA:

1. Determine the number of milligrams of particulate matter collected.
2. Determine the volume of the air sampled in liters.
3. Calculate the number of milligrams of particulate matter per liter.

COMPARISON OF RESULTS:

1. Compare your results with those of your classmates.
2. What level of particulate air pollution is permissable by Federal standards? Consult the Milwaukee Health Department or another appropriate agency.
3. Compare your results with those obtained by the Milwaukee County Pollution Control Board.
4. List 3 or more sources of particulate air pollution other than smokestacks.

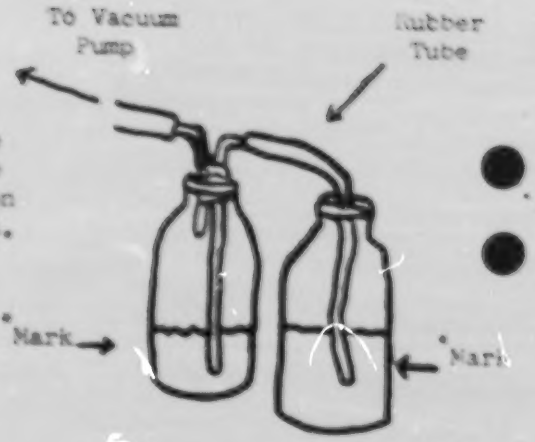
CALIBRATION OF AIR PUMP

MATERIALS:

1. Vacuum pump or vacuum cleaner.
2. Two large bottles (acid bottles).
3. One 2-hole stopper to fit acid bottle.
4. Glass and rubber tubing.
5. Graduated cylinder.

PROCEDURE:

1. Connect apparatus as shown in diagram.
2. Fill jugs with water to levels indicated in diagram and mark.
3. Run vacuum pump until the levels of water are reversed; note time elapsed.
4. Mark new levels of water.
5. Determine the volume of water transferred.
6. Calculate the number of liters transferred per minute.



*Note: The mark on the bottle on the right should be higher than the mark on the bottle on the left.

METHOD 4

INTRODUCTION:

The great majority of organic pollutants in the air are hydrocarbons originating from the incomplete combustion of gasoline in the automobile. Inorganic air pollutants, however, originate primarily from industrial waste, such as fly ash. The fact that hydrocarbons can be further burned, provides a basis for distinguishing between organic and inorganic pollutants.

MATERIALS:

1. Vacuum pump
2. Buchner funnel
3. Filter paper
4. Balance
5. Rubber tubing
6. Crucibles
7. Dessicator
8. Bunsen burner

PROCEDURE:

1. Obtain an air dried weighed sample of particulate matter, using the procedure outlined in the experiment on Quantitative Analysis For Particulate Matter In Air.
2. Heat two crucibles and cool in dessicator (approximately 20 minutes).
3. Weigh crucibles. Insert a blank filter paper into the second crucible.
4. Insert folded filter paper into a crucible.
5. Heat crucibles until filter paper is completely ashed.

6. Cool in dessicator for 20 minutes and reweigh.

7. Determine the weight of the ash in both crucibles.

PROCESSING THE DATA:

1. Find the difference between the weight of ash in the two crucibles. This represents the weight of the inorganic particulate matter.

2. Find the difference between the original weight of particulate matter and the weight obtained above. This represents the weight of organic particulate matter.

3. Calculate the number of milligrams per liter (MG/L) for both the inorganic and organic particulate matter.

4. If possible, sample air at different locations and by comparison of the results, attempt to correlate the area with that type of contaminant.

5. In regard to the differences between organic and inorganic particulate matter:

   a. which is the most harmful to life?

   b. what are the sources of each?

   c. which would be the easiest to control or reduce?

ACTIVITY #2

ASBESTOS, SILICON, BERYLLIUM—AIRBORN HEALTH HAZARDS

OBJECTIVES:

1. The student will become more skilled in the use of library and reference materials.
2. The student will develop skills in editing and summarizing scientific literature.
3. The student will become informed about environmental health hazards.
4. The student will express concern about health hazards.

INTRODUCTION:

In recent years a number of serious respiratory impairments, classified as occupational diseases, have been traced to the invisible dust from substances such as asbestos, silicon, and beryllium.

ACTIVITY:

In this investigation, using library resources, the following considerations must be made:

a. natural forms, processing, and commercial use of the materials;
b. methods by which the particles become airborn;
c. the effects of these particulates on the human body;
d. possible cures for the diseases;
e. occurrences of the diseases in the Milwaukee area;
f. preventative measures against the disease; and,
g. legal protection for affected workers.

Using these guidelines, the student should prepare a written or oral report on one or more of these airborn health hazards.

ACTIVITY #3

SULFUR DIOXIDE IN AIR—QUALITATIVE AND QUANTITATIVE ANALYSIS

OBJECTIVES:

1. The student will discover relationships between sulfur dioxide and water acidity.
2. The student will correlate sulfur dioxide in air with sources of pollution.
3. The student will relate sulfur dioxide content of air to environmental damage.
4. The student will improve his skill in the use of chemical indicators.

QUALITATIVE ANALYSIS

INTRODUCTION:

Sulfur dioxide is a poison and its presence as a contaminant in air has caused death. Killer fogs are lethal primarily because of sulfur dioxide. Sulfur dioxide in air can be oxidized in several ways to sulfur trioxide. This SO_3 will also combine with atmospheric moisture to form H_2SO_4 which can attack car finishes, statues, nylon, stone facings, and metal. The main source of sulfur dioxide in local air is the combustion of coal containing sulfur by power utilities and other industries.

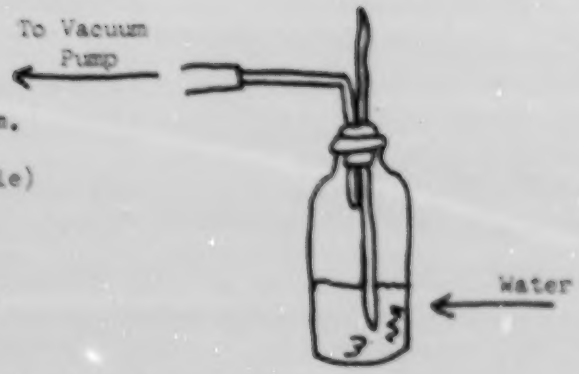
Due to cultural, economic, and social attitudes, we have become dependent upon the use of vast amounts of electricity. In producing electricity, electric power companies use fossil fuels which produce sulfur dioxide when burned. For example, the power plant at Oak Creek, Wisconsin, burns 17,000 tons of coal per day.

When sulfur dioxide combines with water an acid is produced. We shall indirectly attempt to show the presence of sulfur dioxide in an air sample by testing the acidity of the water it pases through.

MATERIALS:

1. pH test paper
2. Vacuum pump or aspirator
3. 250 ml flask with 2-hole stopper
4. Glass tubing
5. Graduated cylinder

PROCEDURE:



1. Assemble apparatus as indicated in diagram.
2. Place 50 ml of water (distilled if possible) in a flask, determine pH using pH paper.
3. Connect the air inlet from vacuum pump to bent glass tube in flask
4. Run vacuum pump for specified period of time; such as 10 minutes. Note time of day and weather conditions.
5. Find the change in pH of the water which is a qualitative measure of the SO_2 in air.
6. An optional activity: obtain some dilute H_2SO_4 and discover how it attacks stone and metal.

PROCESSING THE DATA:

1. Collect 3 air samples for your class: one set of 3 samples for the morning and one set of 3 for the afternoon. Arrange your observations in the following tables:

Date	Time	Weather	pH

Date	Time	Weather	pH

2. Can you find any correlation between your pH data and the time of day the test was run? How can you account for this?
3. Can you find any correlation between your pH data and weather conditions at the time the test was run? If so, how can you account for this?
4. Suggest methods whereby the concentration of sulfur dioxide can be reduced in the air.
5. Find out what "Scrubbing" is. Why don't power plants use this method?
6. How will the quality of coal in the future effect the SO_2 problem?

QUANTITATIVE ANALYSIS

INTRODUCTION:

1. 0.01M solution of $KMnO_4$
2. Buret with glass or plastic stopcock
3. Vacuum pump or aspirator
4. 250ml flask with 2-hole stopper
5. Glass and rubber tubing
6. Air flow meter, if available

PROCEDURE:

1. Calibrate air pump if necessary (see p.4 for calibration instructions).
2. Assemble apparatus as shown in the preceeding experiment on the Qualitative Analysis For Sulfur Dioxide In Air.
3. Place 50ml of water into a 250ml flask.
4. Allow air to bubble through for a given period of time (eg. 30 min.)
5. Record room temperature and atmospheric pressure.
6. Titrate the 50ml of H_2O with 0.01M $KMnO_4$. The end point is represented by the first permanent faint pink color. Record volume of $KMNO_4$ used.

PROCESSING THE DATA:

1. Determine the volume of air used in this experiment and convert to S.T.P.
2. Using the following equation, determine the volume of sulfur dioxide titrated:

$$5SO_2 + 2MnO_4^- + 2H_2O \qquad 2Mn^{++} + 5SO_4^= + 4H^+$$

3. Calculate the number of liters of sulfur dioxide that would be present in 1,000,000 liters of air. This is the parts per million (ppm) of sulfur dioxide in air.
4. In clean air the average concentration for sulfur dioxide is about .0002 ppm. In 1964, Chicago had a daily average of .175 ppm for sulfur dioxide; San Francisco had an average of .017 ppm for sulfur dioxide. The highest level recorded for sulfur dioxide in 1964 was .42 ppm. This roughly 2,000 times the concentration found in clean air. How many times greater than clean air was the sulfur dioxide content of the air you tested?
5. What effect do the following social or economic factors have upon the amount of sulfur dioxide in the air:
   a. Population growth
   b. Increased leisure time
   c. Increased production of aluminum
   d. Increased use of air conditioners

A FOLLOW UP TEACHER DEMONSTRATION:

Formation of H_2SO_4 from SO_2:

1. Burn some sulfur in a combustion spoon and trap some of the SO_2 produced in a gas collecting bottle.
2. Warm a small amount of concentrated nitric acid in a beaker. Dip a piece of paper toweling in the acid and place the paper in the gas collecting bottle with the SO_2.
3. Allow the bottle to stand several minutes so that the SO_2 and NO_2 will react.

4. Add 20 or 30 milliliters of water to the bottle and shake.

5. Test the solution for the presence of SO_4^{-2} ions by adding Ba^{+2} ions. A white precipitate proves that H_2SO_4 was formed.

6. Point out to the student that SO_2 in the air can be similarly oxidized to form sulfuric acid which can cause environmental damage. Also point out that SO_2 can be used as a resource to produce sulfuric acid on a commercial basis.

ACTIVITY #4

SULFUR DIOXIDE AND NITROGEN DIOXIDE--DAMAGE TO MATERIALS

OBJECTIVES:

1. The student will associate nitrogen dioxide and sulfur dioxide pollution with damage to materials.
2. The student will acquire skill in making accurate and detailed observations.
3. The student will experience group interaction in terms of responsibility and cooperation.
4. The student will relate pollution problems to his home envrionment.

INTRODUCTION:

In areas of high population density sulfur dioxide and nitrogen dioxide are usually present in noticeable concentration. Sulfur dioxide is emitted when electric utilities or industries burn coal or sulfur. Nitrogen dioxide is one of the air contaminents released by automobiles. These gases directly threaten our health, however, in this experiment we will study the problems they cause when they attack common materials. Industry is being encouraged by government and civic organizations to work on methods of reducing sulfur dioxide and nitrogen dioxide.

MATERIALS:

1. $NaHSO_3$
2. dilute H_2SO_4
3. Cu
4. conc HNO_3
5. gas collecting bottles with stoppers
6. materials to be tested:
   rubber bands, colored cloth, colored paper,
   nylon green leaves, painted metal and wood

PROCEDURE:

(Suggested approach: let one half of the class work with sulfur dioxide and the other half with nitrogen dioxide. The teacher should set up the gas generator and dispense the gas to the students. Use a fume hood if one is available. Be sure to advise the students one day in advance to bring in materials to be tested.)

1. Fit a flask with a two hole stopper containing a thistle tube and a delivery tube.
2. Place a strong solution of $NaHSO_3$ in the flask, and add dil H_2SO_4 slowly through the thistle tube.
3. Collect enough bottles of SO_2 (by upward displacement of air) to supply half the class.
4. Using the same flask (cleaned), or similar apparatus, place some copper in the flask, add a little water through the thistle tube, and slowly add conc HNO_3 until brown fumes of NO_2 are evolved.
5. Collect enough bottles of NO_2 (by upward displacement of air) to supply the other half of the class.
6. The students should place the materials to be tested in the bottles. Each object must be no larger than one square inch.
7. Let the bottles stand overnight. The next day, remove the materials from the bottles and record any changes.
8. Students who used SO_2 should compare and exchange observations with students who used NO_2.

PROCESSING THE DATA:

1. For each of the two gases describe their color and odor. Are they heavier or lighter than air?
2. Compare the effects of the two gases on the materials tested.

3. Why were these gases collected by displacement in air rather than displacement in water?

4. In your opinion would it be better to have these gases as pollutants in air or dissolved in rain water as acids on the ground?

5. List any materials that come to mind which are not affected by SO_2 and NO_2. How feasible is it to use these materials as substitutes for those which you tested.

6. What plans does industry have to control SO_2 and NO_2 emissions? Indicate any problems related to these plans.

7. A prominent New York doctor (A.L. Barach) believes that baking soda solution sprayed from planes over cities with a high SO_2 pollution level might well eliminate this pollution problem. How would this eliminate SO_2 in the air? How would you adapt this to home use?

ACTIVITY #5

PHOTOCHEMICAL SMOG

OBJECTIVES:

1. The student will gain experience in using the library and reference materials.
2. The student will develop skill in editing and summarizing scientific literature.
3. The student will broaden his knowledge on the problem of photochemical smog.
4. The student will practice making comparisons and evaluations.

INTRODUCTION:

The formation of photochemical smog depends on the presence of certain combinations of air pollutants and is favored by special atmospheric conditions. Atmospheric conditions are closely related to geographical nature of the location. Thus, photochemical smog is more prevalent in certain areas of the country.

ACTIVITY:

In this investigation, using library resources, the following considerations must be made:

a. the air pollutants necessary for smog formation and their sources;
b. the reactions which occur in the process of smog formation;
c. the relation between colloidal particles (dust) and smog formation;
d. description of temperature inversion and its effect on smog formation;
e. methods of measuring the amount of smog pollution;
f. the effects of smog on the immediate environment;
g. an evaluation of the smog problem in Milwaukee as compared to other cities.

Using these guidelines, the student should prepare a written or oral report on photochemical smog.

ACTIVITY #6

POLLUTION ABATEMENT--SCRUBBING AND AFTERBURNING

OBJECTIVES:

1. The student will inquire into some industrial practices for pollution abatement.
2. The student will relate industrial scrubbing to both a reduction of air pollution and to an increase of water pollution.
3. The student will acquire skill in the construction and safe use of a laboratory gas generator.

INTRODUCTION:

The wet scrubber is one of the most common pollution abatement devices used by industry. It demonstrates the fact that when a polluted gas stream is passed through water, the pollutants, some gases, and particulate matter are absorbed by the water. The water used in this process can also become a pollutant unless it is disposed of properly.

In addition to scrubbing there is another more simple industrial process for controlling particulate matter emissions. This process is called afterburning. Afterburning is just the further combustion of matter which originally escaped complete combustion. Afterburning is also used in jet aircraft. Its use in aircraft did not originate over a concern for air pollution, but rather to provide for additional speed and more efficient use of fuel.

This experiment will consist of three parts. Parts one and three will be teacher demonstrations and part two will be a student experiment.

MATERIALS:

1. Marble chips, $CaCO_3$
2. $Ca(OH)_2$ or $Ba(OH)_2$ solution
3. HCL, dilute

4. pH test paper if available

5. Vacuum pump or water aspirator

PART I--DEMONSTRATION OF WET SCRUBBER

PROCEDURE:

1. Obtain three flasks with two hole stoppers in each.
2. Insert an air intake glass tube close to the bottom of flask 1.
3. Connect flask 1 to flask 2 with rubber and glass tubing such that the tube in flask 2 extends nearly to the bottom.
4. Connect flask 2 to flask 3 with rubber and glass tubing such that the tube in flask 3 extends nearly to the bottom.
5. Connect flask 3 to vacuum source.
6. Place crumpled paper in flask 1 and water in flasks 2 and 3.
7. Turn on the vacuum and heat the paper in flask 1 with a Bunsen burner.
8. Observe what happens to the gas and smoke produced as they pass through flasks 2 and 3.

PART II--EFFECT OF SCRUBBING ON WATER

PROCEDURE:

1. Obtain a flask with a one-hole stopper.
2. Fit the stopper with a glass and rubber delivery tube.
3. Place some marble chips in the flask, add 10 ml of dilute HCl, and gently insert the stopper and delivery tube.
4. Bubble the CO_2 gas evolved through 20 ml of either $Ca(OH)_2$ or $Ba(OH)_2$.
5. At one minute intervals record the pH of the solution using pH test paper.
6. Continue until two changes occur in the solution. It may be necessary to add more HCl to the marble chips.
7. Observe and record any changes.

PART III--DEMONSTRATION OF AFTERBURNER

PROCEDURE:

1. Clamp a small piece of rubber tubing on a ring stand.
2. Clamp an inverted funnel over the rubber.
3. Ignite the rubber thus producing a stream of black smoke.
4. As the smoke leaves the funnel, ignite it with the burner.

PROCESSING THE DATA:

1. Why are some gaseous pollutants more easily removed by scrubbing than others.
2. Write the equation for the reaction of CO_2 with water.
3. If the water used for scrubbing becomes hot, what will be the effect on the process?
4. In PART II why does a precipitate first form and then disappear?
5. Write an equation for the reaction between marble chips and HCl.
6. How can you tell when combustion is incomplete?
7. How would you find out which factories in Milwaukee use wet scrubbers?
8. Suggest some methods for disposing of the liquids resulting from scrubbing.
9. Find out what control methods for stack emissions are used in your school.

ACTIVITY #7

TURBIDITY REDUCTION IN WATER

OBJECTIVES:

1. The student will trace ecological problems to turbid water.
2. The student will learn that turbid water can be cleaned by more than one method.
3. To give the student practice in making judgements between various techniques.
4. The student will learn that pollution abatement can be costly.

INTRODUCTION:

Particles are everywhere in natural water and they vary greatly in size, density, and concentration. Greater concentrations of particles result in more cloudy or turbid waters. Particles can absorb substances in water and serve as sites for bacterial growth. They also act to transport and deposit pollutants. DDT, is transported by particulate matter, which when it settles, provides a long lasting source of contamination. Animal life in water frequently communicates by means of chemical messages, which can be disrupted by turbidity. Most importantly, turbidity in water limits the penetration of sunlight, thereby greatly reducing the photosynthetic process of aquatic plants. This causes a weakness at a crucial link in the food chain, threatening the survival of all other forms of life. In addition to these fundamental problems, caused by turbidity of water, the asthetic appeal of clean water cannot be "overlooked." Contrast canoeing in the Milwaukee River with canoeing in Alaska.

MATERIALS:

1. Minimum of 4 test tubes
2. 1M $Al_2(SO_4)_3$
3. Dilute NH_4OH solution
4. Filter paper and funnel
5. Light Box, made with an overhead projector and a sheet of white paper.
6. At least 300ml of water from a river, lake, pond, etc.

PROCEDURE:

1. Obtain at least 300ml of turbid water to be tested.
2. Divide your sample into 3 equal portions.
3. Leave one portion untreated.
4. Filter the second portion.
5. To the third portion add 10 ml of dil NH_4OH solution and 10 ml of 1M $Al_2(SO_4)_3$.
6. Shake the third portion well and allow to settle overnight.
7. Fill each of four test tubes to the same level with:
   a. untreated sample
   b. filtered sample
   c. chemically treated sample
   d. tap water
8. Make a light box by placing a piece of clean white paper on an overhead projector.
9. Compare the turbidity of the four samples by holding them above the overhead projector and looking down at the test tubes over the bright white surface.

PROCESSING THE DATA:

1. What distinctions can be made between your filtered and chemically treated samples?
2. Flocculation is the process by which certain chemicals form clumps of solids in solutions. Why is flocculation used in the filtration of drinking water but not for the treatment of sewage in Milwaukee?
3. What problems would be encountered in attempting to chemically clean a river?
4. What is meant by a combined sewer system? How does Milwaukee's combined sewer system contribute to the turbidity of Lake Michigan?
5. Why does increased turbidity raise the temperature of water? What effect does this have on the ecosystem?

ACTIVITY #8

ACIDITY IN WATER--QUALITATIVE DETERMINATION

OBJECTIVES:

1. The student will relate acid-base theory to a practical situation.
2. The student will become concerned about an aspect of water quality in their local environments.
3. The student will develop skill in the use of acid-base indicators.
4. The student will develop skill in recording data.
5. The student will make comparisons of water from different locations.

INTRODUCTION:

In every environment there are factors which limit the number of organisms living within that environment. Such factors determine the environment's carrying capacity. One factor influencing carrying capacity in a water environment is the acidity or alkalinity of the water. Most aquatic life can exist in a pH range from 6 to 9. Beyond these limits of acidity and alkalinity water is harmful to life. To illustrate that this range is indeed narrow, soda pop has a pH of about 3. Agricultural fertilizers and certain industrial wastes are the prime causes of pH changes in aquatic environments.

MATERIALS:

1. pH paper or pH meter
2. bromthymol blue indicator } optional
3. methyl red indicator }

PROCEDURE:

1. Place water samples to be tested in suitable containers.
2. If pH paper or pH meter is to be used, test each sample and record.
3. If indicators are to be used, divide each sample into 2 equal portions.

4. Place a drop of bromthymol blue indicator into one half of the sample and a drop of methyl red indicator into the other half.

5. Consult a handbook of chemistry to see what the pH range of each indicator is.

PROCESSING THE DATA:

1. Record your data in the following table:

Sample Number	Location	Date	Time	pH

2. Attempt to relate the pH of your various samples with sources of contamination.

3. Name four industries which are located on rivers in the metropolitan Milwaukee area. Do they use the river? If so, how?

4. How could you prevent a specific industry from polluting water?

5. In several instances limestone rocks have been placed in rivers to act as sieves. This was done to reduce water contamination from acid mine drainage. Where can information on this be found? Explain how this works and include one or more equations.

6. (Optional research activity):

   a. Find an example of a fertilizer and explain how it changes the pH in water.

   b. Find an example of an industrial waste and explain how it changes the pH in water.

ACTIVITY #9

DISSOLVED OXYGEN--QUANTITATIVE ANALYSIS (TWO METHODS)

OBJECTIVES:

1. The student will practice evaluating water quality in regard to dissolved oxygen.
2. The student will apply a standard method of analyzing for dissolved oxygen to a series of water samples.
3. The student will make comparisons of water from different locations.
4. The student will develop skill in recording data.

INTRODUCTION:

An adequate supply of pure water is essential to life. One important characteristic of pure water is a high content of dissolved oxygen. Often in polluted lakes and rivers the amount of dissolved oxygen has been reduced by micro-organisms which utilize oxygen as they digest nutrient material in the water. Through our disposal of waste, we increase the nutrient material available to these micro-organisms. They multiply into vast numbers leaving little oxygen remaining for other plants and fish which eventually die off. This process has virtually eliminated the life support ability in much of our Milwaukee River.

METHOD I

By using the technique described in this experiment, we can rank a series of water samples as to dissolved oxygen content.

MATERIALS:

1. Methylene blue solution with one of the following concentrations depending upon sample used:
   a. .1g with 100 ml of distilled water
   b. .1g with 500 ml of distilled water

c. .1g with 1,000 ml of distilled water

PROCEDURE:

1. Add one drop of methylene blue to each test tube to be tested.
2. Fill one test tube completely with tap water as a control.
3. Fill and stopper tightly other test tubes completely with the samples to be tested.
4. Label test tubes as to location of sample.
5. Record time needed for blue color to disappear from each test tube.
6. If the time for color change is too long, dilute the methylene blue solution 5 to 10 times.

PROCESSING THE DATA:

1. Tabulate your data in the following table:

Sample Number	Location	Time

2. List the probable causes of pollution within the various samples you tested.
3. What effect do the following factors have upon the oxygen content of water:
   a. speed of the river
   b. temperature
   c. rain
4. What is "B.O.D"? How is it related to dissolved oxygen content in water?
5. What would be the effects of having a clean Milwaukee River?
6. How might we go about beginning to clean up the Milwaukee River?

METHOD 2

The procedure used in this experiment is a standard procedure used throughout the United States. It is adopted from Standard Methods for The Examination of Water and Waste Water, by the American Public Health Association. This experiment illustrates some of the modern analytical techniques used in water-quality study. The following equations summarize the chemical reactions involved.

$$MnSO_4\ (aq) + 2KOH(aq) \longrightarrow \underset{\text{white}}{Mn(OH)_2\downarrow} + K_2SO_4\ (aq)$$

$$2Mn(OH)_2 + O_2(aq) \longrightarrow 2MnO(OH)_2\downarrow \text{ brown}$$

$$MnO(OH)_2 + 2H_2SO_4\ (aq) \longrightarrow Mn(SO_4)_2(aq) + 3H_2O$$

$$Mn(SO_4)_2 + 2KI(aq) \longrightarrow MnSO_4(aq) + K_2SO_4(aq) + I_2(aq)$$

$$2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6\ (aq) + 2NaI(aq)$$

MATERIALS:

1. 1-100 ml stoppered flask
2. titrating burette
3. pipette or medicine dropper
4. 1-250 ml beaker
5. boiled starch indicator (1g starch per 100 ml H_2O)
6. 3.2M $MnSO_4$
7. .025M $Na_2S_2O_3$
8. alkaline iodide solution (70g of KOH & 1.5g of KI 100ml of water)
9. conc. H_2SO_4

PROCEDURE:

1. Accurately determine the volume of a 100ml stoppered flask when completely filled.
2. Fill a 100ml flask completely with the sample to be tested and stopper tightly.

3. Add 1ml of 3.2M $MnSO_4$ by inserting tip of pipette into sample to be tested.
4. Add 1ml of alkaline iodide solution in the same manner.
5. Insert stopper (a small amount of spillage will occur) and shake for one half minute.
6. Add 1ml of conc. H_2SO_4 in the same manner as above using a pipette.
7. Mix thoroughly, stopper and allow to stand for 10 minutes.
8. Transfer the sample to be tested to a 250ml beaker, add 1ml of starch indicator.
9. Titrate with .025M $Na_2S_2O_3$. The end point is reached when the blue color disappears.

PROCESSING THE DATA:

1. Calculate the weight of oxygen in the sample using the following information:
   a. One mole of oxygen gas is equivalent to four moles of $Na_2S_2O_3$.
   b. The number of moles of $Na_2S_2O_3$ used equals the volume in liters used times its molarity.
2. Calculate the number of milligrams of oxygen per liter of sample. This is also called the parts per million of sample (ppm). Compare your results with the maximum amount of oxygen that can be dissolved per liter, at room temperture. (Consult a handbook for this information).
3. Propose reasons why some samples contain more oxygen than others.
4. What is being done and what more can be done to increase the oxygen content of our waters?
5. Find out if the dissolved oxygen content in water is measured on a regular basis in Milwaukee? As a start, contact the Sewage Commission and the Health Department.

   Note: These agencies will probably talk about "B.O.D." Be sure you understand this term before you call.

Note: Only one student per class should call.

6. Why worry about dissolved oxygen content as a measure of water quality?

ACTIVITY #10

MINERAL LEACHING OF SOILS

OBJECTIVES:

1. The student will obtain first-hand evidence that minerals can be leached out of soil.
2. The student will correlate soil leaching to the production of food.
3. The student will describe how soil leaching promotes water pollution.

INTRODUCTION:

Most soils contain minerals and nutrients. Some of these are partially soluble in water and are leached out during periods of heavy rainfall. Runoff, or the excess rainfall not absorbed by the soil, will flow to the nearest stream, river, or lake. At that point the runoff can become a pollutant, especially if it carries dissolved fertilizers from agricultural lands. Municipalities and state authorities are actively involved in dealing with the problems of runoff contamination.

MATERIALS:

1. Ferric sulfate
2. .2M KSCN solution
3. Cotton or glass wool
4. Soil samples from students' homes

PROCEDURE:

(Note to the instructor: the day before the experiment the students should be told to bring soil samples to school. Make sure that a variety of dry soils are chosen such as sand, clay, black dirt, etc. Also, make a table on the blackboard in which to record group data such as type of soil and leaching rate.)

1. Weigh out .5 grams of $Fe_2(SO_4)_3$.

2. Mix this chemical with 25 ml of the soil to be tested.
3. Place a wad of cotton or glass wool in a funnel and place the soil on top of the wad.
4. Pour 100 ml of water slowly into the funnel.
5. Collect the effluent in 10ml portions.
6. Add 1 ml of .2M KSCN to each 10ml portion. A red coloration indicates the presence of iron.
7. Record the following data on a table on the blackboard:

   Type of soil (sand, clay, brown dirt, black dirt, etc.)

   Leaching rate (fast, medium, slow, none)
8. Copy the table and all group data.

PROCESSING THE DATA:

1. Draw any conclusions you can about different soils based on the information in the group data table.
2. Why do some soils leach more easily than others?
3. What is a watershed? How do watersheds, contour farming, and leaching of soils relate to one another?
4. Cheap fertilizers have been known to quickly turn a lawn green for a short period of time. More expensive fertilizers have slower, long-lasting effects. Explain this contrast in terms of the chemical solubility of the fertilizer.
5. Explain why a tropical forest has few nutrients in the soil even though the humus content is thick?

ACTIVITY #11

HARDNESS OF WATER--QUANTITATIVE ANALYSIS (TWO METHODS)

OBJECTIVES:

1. The student will analyze and compare various samples of water for hardness.
2. The student will familiarize himself with a standard laboratory test for water hardness.
3. The student will write equations symbolizing the softening of hard water.
4. The student will perceive the value of soft water.

INTRODUCTION:

Hardness is a characteristic of water which contains dissolved salts. A variety of salts can cause hardness. The bicarbonates, carbonates, sulfates, chlorides, and nitrates of such elements as calcium, magnesium, and iron will all impart hardness to the water. In Milwaukee water the most common salt is calcium carbonate. It originates when raindrops falling through the atmosphere absorb carbon dioxide gas. The raindrops then become a weak solution of carbonic acid. When the slightly acid rainfall moistens chalk or limestone rock it reacts chemically to form a solution of calcium carbonate. The rainwater has become "hardened." Some hardwater is deemed "temporarily hard" because boiling will remove the undesirable calcium bicarbonate. Other hardwater is "permanently hard" because of dissolved chlorides or sulfates of magnesium, calcium or iron.

Hardwater causes numerous problems. At home it will form a scum with soap during washing. Not only is the scum difficult to remove from clothing but more soap is required for the washing process. Hardwater will also facilitate precipitation or scaling in teas kettles, irons, and pipes. Sometimes it causes objectionable taste or odor in water. However, small or moderate amounts of dissolved minerals will enhance the flavor of water.

Soft water is simply water which has not flowed over any countryside and has not dissolved any of the minerals which would make it hard.

Reference Data from U.S. Public Health Standards:	Hardness (ppm)	Classification of water
	0-60	safe
	61-120	moderately hard
	121-180	hard
	181-	very hard

METHOD 1

MATERIALS:

1. Distilled water
2. A soluble calcium salt
3. Sodium carbonate
4. Soap solution in dropping bottles.

   Soap solution can be made by dissolving 100 grams of castile soap in one liter of 50% alcohol.

PROCEDURE:

1. Place 10 ml of distilled water in a test tube.
2. Add soap solution a drop at a time with shaking, until suds cover the water surface for one minute. Count and record the number of drops.
3. Place 10 ml of tap water in a test tube and count and record the number of drops of soap needed to produce the same amount of suds.
4. Boil some tap water in a beaker. Test 10 ml of the boiled water with soap. Record the number of drops needed.
5. Dissolve a pinch of a soluble calcium salt in a beaker of water:

   a. Test 10ml of this with soap solution. Record the number of drops needed.

b. Place another 10 ml in a test tube, add a pinch of sodium carbonate, and test with soap solution. Record the number of drops of soap needed.

c. AN OPTIONAL ACTIVITY: Standardize the soap solution by using a water sample of known hardness. Milwaukee water has a hardness of 140 parts per million of calcium carbonate. Be sure to subtract the number of drops needed for distilled water from the number needed for the standard. Calculate the ppm of hardness per drop of soap. Now test water from various sources for hardness. Remember to subtract the number of drops needed for distilled water.

PROCESSING THE DATA:

1. What is the difference between temporary hard water and permanent hard water?
2. Soap is $C_{17}H_{35}COONa$. Write the equation for the reaction of soap and calcium.
3. Write an equation for what happens when sodium carbonate is added to hard water.
4. How can the scale in an old tea kettle be chemically removed?
5. Would you rather drink hard water or softwater? Why?
6. List several sources of error in this method of testing water for hardness.
7. Relate hardness of water, use of detergents, and eutrophication.

METHOD 2

This method of testing for water hardness is one of the most precise ever divised. It is used more than any other method in all parts of the country because the results obtained are very reliable. Be sure to use distilled water to make the reagents.

MATERIALS:

1. EDTA solution. Dissolve 4 grams of disodium dihydrogen ethylenediaminetetraacetate (EDTA) and .86 grams of NaOH in one liter of solution.

2. Indicator. Dissolve 1 gram Eriochrome Black T and about .06 grams of $Na_2CO_3.H_2O$ in 30ml of water and dilute to 100ml with isopropyl alcohol.

3. Buffer. Dissolve 40 grams Borax, 10 grams NaOH, and 5 grams sodium sulfide in one liter of solution.

4. .1 mole of a soluble calcium salt: 1.11 gram of $CaCl_2$ or 1.47 gram of $CaCl_2.2H_2O$ or 1.64 grams of $Ca(NO_3)_2$ or 1.58 grams of $Ca(C_2H_3O_2)_2$.

PROCEDURE:

Standardization of EDTA

1. Dissolve .1 mole of calcium salt in one liter of solution. (Each ml of this solution is now equivalent to one milligram of calcium carbonate.)
2. Place exactly 25 ml of this in a flask or beaker.
3. Add one ml of buffer and 3 drops of indicator.
4. Titrate with EDTA until the last trace of red disappears and the solution is blue.

Testing for Hardness

1. Place 100 ml of the water to be tested in a flask or beaker.
2. Add 2 ml of buffer and 8 drops of indicator.
3. Titrate with EDTA.

PROCESSING THE DATA:

1. Determine how many milligrams of $CaCO_3$ each milliter of EDTA is equivalent to. To do this divide ml of standard by ml of EDTA.
2. How many milligrams of $CaCO_3$ are equivalent to the minerals in the sample of water you tested? (Multiply the answer from number 1 times ml of EDTA.)
3. What would be the hardness (in mg of $CaCO_3$) if the volume of the sample was one liter? This is the hardness of the water in either milligrams per liter or parts per million.
4. Why is water in Waukesha harder than Milwaukee water?

ACTIVITY #12

SOAPS AND DETERGENTS--COMPARATIVE STUDY

OBJECTIVES:

1. The student will make comparisons between soaps and detergents.
2. The student will develop his skill in the use of the library.
3. The student will evaluate soaps and detergents in terms of their cleansing efficiency.
4. The student will evaluate soaps and detergents in terms of their impact on the environment.
5. The student will describe the molecular structures of soaps and detergents.

INTRODUCTION:

Soaps have been used since prehistoric times. Only recently have detergents been used by man. In the 1950's, through massive advertising campaigns, people were made aware of the values of detergents and switched from soaps to detergents on a large scale. A huge billion dollar industry resulted. In the early 1960's detergents were in the news. Serious environmental problems, beginning to appear, were being traced to the massive use of detergents. Again in the 1970's detergents were in the news because of their relationship to additional environmental problems.

ACTIVITY:

In this investigation, using library resources, the following considerations should be made:

a. how soaps clean;
b. basic raw materials for making soaps and detergents;
c. why detergents replaced soaps;
d. an elaboration on the problem of foaming, the original environmental problem of detergents;
e. the role of the surfactant and the builder in a detergent;

f. the difference between the structural formulas of biodegradable and non-biodegradable detergents;

g. other problems recently associated with detergents; and

h. federal or state legislation concerning the manufacture and sale of detergents.

Using these guidelines, the student should prepare a written or oral report on soaps and detergents.

ACTIVITY #13

PHOSPHATES IN WATER--QUALITATIVE ANALYSIS

OBJECTIVES:

1. The student will describe a process for removing phosphates from water.
2. The student will differentiate between detergents and soaps.
3. The student will relate phosphate content of water to algae growth as an environmental problem.
4. The student will correlate phosphate concentration in water with his personal life.

INTRODUCTION:

Detergents and fertilizers are the primary causes for phosphate pollution in water. Just as phosphates fertilize land plants, they also fertilize aquatic vegetation to grow beyond the carrying capacity of their water environment. This carrying capacity is exceeded when sunlight cannot penetrate to lower layers of plants, causing them to die and sink to the bottom. Bacteria which then feed on the dead plants reduce the oxygen level in the water. Individual uses of phosphates, duplicated or compounded overtime, produce significant environmental alterations.

MATERIALS:

1. test tube
2. 250ml beaker
3. Bunsen burner
4. 3M HNO_3 (dilute)
5. 1M $(NH_4)_2MoO_4$

PROCEDURE:

1. Obtain samples to be tested:
   a. known phosphate solution

b. detergent solutions

c. water samples

2. Place 5 drops of the samples to be tested in a test tube.

3. Add 4 drops of 3M HNO_3 and 4 drops of 1M $(NH_4)_2MoO_4$.

4. Heat in a water bath for 2 minutes.

5. Yellow precipitate indicates the presence of phosphates in the sample.

PROCESSING THE DATA:

1. Why are phosphates present in detergents but seldom in soaps?

2. Find out how sewage treatment plants remove phosphates. How difficult is the process?

3. Why does the phosphate concentration of the Milwaukee River increase after a rain?

4. What can you do personally do to reduce the phosphate concentration of our water?

ACTIVITY #14

ACTIVATED CARBON--REMOVAL OF COLOR AND ODOR FROM WATER

OBJECTIVES:

1. The student will observe directly the adsorptive properties of activated carbon.
2. The student will relate the adsorptive properties of activated carbon to water purification.
3. The student will do library research on the phenomenon of adsorption.

INTRODUCTION:

Activated carbon is an interesting substance because it is used as a purifier in so many diverse ways. It was the primary agent used in gas masks during World War I, when the wearer needed protection from lethal chlorine gas. Activated carbon has been used in the sugar refining process during the transformation of brown sugar to white sugar. Today, activated carbon is of interest as it functions to remove undesirable tastes and odors from water during water purification. Everyday at the Water Purification Plant in Milwaukee, the adsorptive properties of activated carbon are utilized to make water from Lake Michigan pleasant tasting.

MATERIALS:

1. Activated carbon or decolorizing charcoal.
2. Brown sugar water or scorched white sugar dissolved in water.
3. Chlorine water made by adding a few ml of HCl to a chlorine bleach.
4. Filter paper.
5. Any organic dye or indicator.

PROCEDURE:

(Note to instructor: the day before the experiment, remind the students to bring a small amount of ground to class.)

1. Thoroughly mix some ground with water and filter it. Examine the filtrate and record its appearance.
2. Thoroughly mix 30 ml of the filtrate with a spoonful of activated carbon and filter again, using a clean filter paper. Compare this filtrate to the first filtrate.
3. Thoroughly mix 30 ml of brown sugar water with a spoonful of activated carbon and filter. Compare the filtrate to the original solution.
4. Cautiously smell some chlorine water. Thoroughly mix 30 ml of it with activated carbon and filter. Compare the odor of the filtrate to the odor of the original solution.
5. Thoroughly mix 30 ml of an organic dye solution with a spoonful of activated carbon and filter. Compare the filtrate to the original solution.
6. An optional activity: Change brown sugar to white sugar.

PROCESSING THE DATA:

1. How does activated carbon differ from ordinary carbon?
2. What is the difference between adsorption and absorption?
3. Why are catalysts often used in the colloidal state?
4. In what way does activated carbon relate to the reduction of lung cancer in a segment of the population?
5. The carbon granules used by water purification plants eventually become saturated with contaminants in the water. How can the carbon granules be rejuvenated?

ACTIVITY #15

LEAD--QUALITATIVE DETERMINATION

OBJECTIVES:

1. The student will test for lead in samples from his immediate environment.
2. The student will realize that lead poisoning is completely unnecessary and avoidable.
3. The student will express the importance of finding substitutes for lead.

INTRODUCTION:

All living organisms interact among themselves and their environment. In the course of technological advances, lead has been used to develop improved paints and gasoline. At the time of their introduction into the environment these developments were welcomed. It was not realized how years later we would be experiencing an environmental loss in the form of lead poisoning; for example, children have died in every major city in our country after eating flaking paint from walls in old houses. When leaded gasoline is burned in automobiles, lead and lead bromide are expelled into the air and onto the soil. One recent investigation suggests that the Northern Hemisphere contains about 1,000 times more lead than if man were not a contributor. Such acts are likely to result in further concentration of lead in some food chains leading ultimately to toxic doses for man or for some other important organisms. Since the determination of lead in air is difficult, we will confine ourselves to the testing of solids.

MATERIALS:

1. Test tubes - 2
2. Beaker
3. Source of heat

4. Dilute HNO_3

5. 1M $K_2Cr_2O_7$ solution

6. 1M Na_2S solution freshly made

7. Samples to be tested:

   a. Solid lead

   b. Pencil paint

   c. Paint from an old house

   d. Tooth paste tube

   e. Dust collected from near a freeway

8. 4M NaOH solution

PROCEDURE:

1. Add 2 ml of HNO_3 to a small amount of the sample.

2. Heat test tube in a beaker of boiling water for two minutes.

3. Add 10ml of water and divide into two portions.

4. Add one drop of $K_2Cr_2O_7$ and 2 ml of 4 M NaOH to the first portion . A yellow precipitate indicates the presence of lead.

5. Add one drop of Na_2S to the second portion. A black color confirms the presence of lead.

PROCESSING THE DATA:

1. Collect data from the entire class and arrange it in table form, showing where the samples came from and whether or not they contained lead.

2. How does lead improve gasoline and paint?

3. Compare the cost of leaded paint and gasoline with that of non-leaded types.

4. Short term economic gains have often produced long term environmental losses. How can we help to prevent this from happening in the future?

ACTIVITY #16

ALUMINUM--PROCESSING AND USE

OBJECTIVES:

1. The student will outline the steps in an industrial process for producing aluminum.
2. The student will investigate the location and availability of raw materials required for aluminum production.
3. The student will relate energy consumption to aluminum production.
4. The student will establish the limitations and potential uses of aluminum.
5. The student will identify aluminum objects in his home.

INTRODUCTION:

Although aluminum is the most abundant metal on the surface of the earth, it is never found in its elementary state. It is so chemically active that it can only be found in combination with other elements. All the aluminum with which we are so familiar is man-made. In order to produce this aluminum, vast amounts of electricity were used along with natural resources, some of which came from foreign lands.

ACTIVITY:

In this investigation, using library resources, the following considerations must be made:

a. an illustrated diagram of the process used in aluminum production;
b. the physical changes and chemical reactions involved in the production process;
c. the availability of the ores and raw materials;
d. how the production and use of aluminum contributes to world pollution;
e. discovery of all uses of aluminum in the home;

f. a listing of industries that use large quantities of aluminum; and

g. the problems of aluminum waste.

Using the above guidelines the student will prepare a written or oral report on aluminum.

ACTIVITY #17

ALUMINUM--A SELF-PROTECTING METAL

OBJECTIVES:

1. The student will compare the chemical activity of aluminum to iron.
2. The student will correlate the chemical activity of aluminum with its commercial uses.
3. The student will describe the connection between the chemical properties of aluminum with our solid waste problems.
4. The student will transfer his concerns about laboratory safety to industrial safety during applications of chemistry.

INTRODUCTION:

Uses of aluminum are limited because of aluminum's high activity, yet aluminum creates a solid waste problem because of its inactivity. This paradox deserves clarification. Although pure aluminum is very active it quickly acquires an oxide coating when exposed to air which prevents chemical reaction unless the coating is penetrated or dissolved.

During the production of aluminum, vast amounts of energy are consumed. When aluminum reacts to form compounds this energy is released. An example is the Thermite Reaction which will be demonstrated in this experiment. These types of reactions, whether done in the laboratory or in industry, create safety hazards to individuals.

MATERIALS:

1. Aluminum (wire or foil)
2. Iron (wire or nails)
3. 6 M HCl solution
4. 6 M NaOH solution
5. Al powder

6. Fe_2O_3

7. Magnesium ribbon

PROCEDURE:

1. Add 5 ml or 6 M HCl to each of two test tubes.
2. Place a piece of Al in one and a piece of Fe in the other.
3. Repeat using 6 M NaOH instead of 6 M HCl.
4. Allow the 4 test tubes to stand for 5 minutes. Record all evidence of chemical change.
5. Pour about 1 ml of the solution containing Al and NaOH into a clean test tube. Add 6 M HCl drop by drop until two changes are noted.
6. The Thermite Reaction. (A teacher demonstration):
   a. Thoroughly mix 5.4 grams of powdered aluminum and 16 grams of Fe_2O_3.
   b. Place this in a filter paper supported on a ring stand over a large pan of sand supported on blocks.
   c. Insert a strip of magnesium to act as a fuse.
   d. Have the students stand 20 feet away and light the magnesium with a Bunsen burner. STAND BACK. HAVE A FIRE EXTINGUISHER AVAILABLE.
   e. After the reaction, pick up the red hot iron with tongs, cool in water, and pass around the class.

PROCESSING THE DATA:

1. Why does aluminum start reacting more slowly than iron? What does this have to do with solid waste disposal?
2. Write equations showing how both HCl and NaOH dissolve aluminum oxide.
3. Write equations showing how both HCl and NaOH dissolve aluminum.
4. Write two equations for the reactions which occurred in step 5 of the experiment.
5. Write the equation for the Thermite Reaction.

6. The heat of formation of Fe_2O_3 is -200 kcal/mole. The heat of formation of Al_2O_3 is -400 kcal/mole. Determine the amount of heat liberated in the Thermite reaction per mole of Fe_2O_3.

7. What do you know about the activation energy of the Thermite Reaction?

8. How do you know that $Al(OH)_3$ is amphiprotic?

9. Find some aluminum cans which have a special inside coating. What food or liquid was in the can? Why was the can coated?

10. In industry the Thermite Reaction is used for welding cracks in propeller shafts and rails. What safety precautions and devices should be used in this operation?

ACTIVITY #18

ENVIRONMENTAL MONITORING--INSTRUMENTS

OBJECTIVES:

1. The student will outline the basic theory behind the operation of various monitoring instruments.
2. The student will correlate the use of certain instruments to their need in monitoring environmental pollutants.
3. The student will develop his skills in the use of library materials.

INTRODUCTION:

Instruments used to monitor the environment are similar to other scientific instruments in that they extend the sensory perceptions of the human body. Instruments provide numerical data which can be compared to other data collected at other times and in other places. Instruments conserve manpower and provide convenient methods of collecting around-the-clock.

ACTIVITY:

In this investigation, using library resources, the following considerations must be made:

a. outlines of the basic theory behind the operation of some of these instruments: spectrophotometer, spectrometer, fluorescent detector, radiometer, gas chromatograph, colorimeter, and microwave scanner;
b. relation of each instrument studied to a specific pollutant which it measures;
c. discover what various instruments are used by monitoring agencies and universities in Milwaukee.

Using the above guidelines the student should prepare a written or oral report.

ENVIRONMENTAL CHEMICAL EQUATIONS

SULFUR DIOXIDE IN AIR

$$S + O_2 \longrightarrow SO_2$$

$$2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

$$SO_3 + H_2O \longrightarrow 2H^+ + SO_4^{-2}$$

$$SO_2 + H_2O \longrightarrow 2H^+ + SO_3^{-2}$$

$$5SO_3^{-2} + 2MnO_4^- + 6H^+ \longrightarrow 2Mn^{+2} + 5SO_4^{-2} + 3H_2O$$

$$CaCO_3 + 2H^+ \qquad CO_2 + Ca^{+2} + H_2O$$

SULFUR DIOXIDE AND NITROGEN DIOXIDE--DAMAGE TO MATERIALS

$$HSO_3^- + H^+ \longrightarrow SO_2 + H_2O$$

$$Cu + 4H^+ + 2NO_3^- \longrightarrow 2NO_2 + Cu^{+2} + 2H_2O$$

POLLUTION ABATEMENT

$$CaCO_3 + 2H^+ \longrightarrow CO_2 + Ca^{+2} + H_2O$$

$$Ca^{+2} + 2OH^- + CO_2 \longrightarrow CaCO_3 + H_2O$$

$$CO_2 + H_2O \longrightarrow 2H^+ + CO_3^{-2}$$

$$CaCO_3 + 2H^+ \longrightarrow CO_2 + Ca^{+2} + H_2O$$

PHOTOCHEMICAL SMOG

$$2NO + O_2 \longrightarrow 2NO_2$$

$$NO_2 \xrightarrow{\text{light}} NO + [O] \text{ atomic oxygen}$$

$$O_2 + [O] \longrightarrow O_3$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

TURBIDITY REDUCTION IN WATER

$$Al^{+3} + 3OH^- \longrightarrow Al(OH)_3$$

ACIDITY IN WATER

SO_2, SO_3, NO, and CO_2 react with water to form hydrogen ions.

DISSOLVED OXYGEN

$$Mn^{+2} + 2OH^- \longrightarrow Mn(OH)_2$$
white

$$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2$$
brown

$$MnO(OH)_2 + 4H^+ \longrightarrow Mn^{+4} + 3H_2O$$

$$Mn^{+4} + 2I^- \longrightarrow Mn^{+2} + I_2$$

$$I_2 + 2S_2O_3^{-2} \longrightarrow S_4O_6^{-2} + 2I^-$$

MINERAL LEACHING OF SOILS

$$Fe^{+3} + SCN^- \longrightarrow FeSCN^{+2}$$

HARDNESS OF WATER

$$2C_{17}H_{35}COONa + Ca^{+2} \longrightarrow (C_{17}H_{35}COO)_2Ca + 2Na^+$$

$$Ca^{+2} + CO_3^{-2} \longrightarrow CaCO_3$$

HARDNESS OF WATER (continued)

$$H_2Y^{-2} + Ca^{+2} \longrightarrow CaY^{-2} + 2H^+$$

Y represents the ethylenediaminetetraacetate radical.

PHOSPHATES IN WATER

$$PO_4^{-3} + 3NH_4^+ + 12MoO_4^{-2} + 24H^+ \longrightarrow (NH_4)_3PO_4 \cdot 12MoO_3 + 12H_2O$$

LEAD--QUALITATIVE DETERMINATION

$$Pb + 4H^+ + 2NO_3^- \longrightarrow Pb^{+2} + 2NO_2 + 2H_2O$$

$$Pb^{+2} + Cr_2O_7^{-2} + H_2O \longrightarrow PbCrO_4 + CrO_4^{-2} + 2H^+$$

yellow

$$Pb^{+2} + S^{-2} \longrightarrow PbS$$

black

ALUMINUM--A SELF-PROTECTIVE METAL

$$2Al + 6H^+ \longrightarrow 2Al^{+3} + 3H_2$$

$$2Fe + 6H^+ \longrightarrow 2Fe^{+3} + 3H_2$$

$$2Al + 6OH^- \longrightarrow 2AlO_3^{-3} + 3H_2$$

$$Al(OH)_3 + 3H^+ \longrightarrow Al^{+3} + 3H_2O$$

$$AlO_3^{-3} + H^+ \longrightarrow Al(OH)_3$$

$$Al^{+3} + 3OH^- \longrightarrow Al(OH)_3$$

$$Al(OH)_3 + 3OH^- \longrightarrow AlO_3^{-3} + 3H_2O$$

EQUATIONS FOR GASOLINE COMBUSTION (additional equations)

$$(C_2H_5)_4 + 13O_2 \longrightarrow 8CO_2 + 10H_2O + Pb$$

$$C_8H_{18} + 10O_2 \longrightarrow 3CO + C + 4CO_2 + 9H_2O$$

$$N_2 + O_2 \xrightarrow{\text{high temp}} 2NO$$

TABLE

SELECTED ENVIRONMENTAL POLLUTANTS

POLLUTANT	PRINCIPAL MAN-MADE SOURCES	DISTRIBUTION IN THE ENVIRONMENT	APPROXIMATE LEVELS	RELEVANT CHEMISTRY AND ENVIRONMENTAL INTERACTIONS	EFFECTS ON MAN'S HEALTH	EFFECTS ON THE ENVIRONMENT	REMARKS
Carbon dioxide (CO_2)	Carbonaceous fuel combustion for energy production, heating and transport. Estimated global emission from combustion about 1.5×10^{13} kg/year	Air and water (global)	Normal atmosphere ~320 ppm Rate of increase ~0.6 ppm/year	a. Biological processes provide a natural system for uptake and replenishment of CO_2. b. The mass of CO_2 in the ocean layer which is in exchange with the atmosphere is 5-8 times the mass of CO_2 in the atmosphere.	Only indirect through possible modification of global climate.	Possible increase in earth's surface temperature (long-range effect).	Normal constituent of the atmosphere essential for plant life.
Carbon monoxide (CO)	Incomplete combustion of carbonaceous matter (motor vehicles, industrial processes, solid waste disposal, forest fires). Estimated global emission from technological sources and forest fires, about 2.5×10^{11} kg/year	Air (local and regional)	Very variable depending on local conditions. Maximum values close to heavy traffic range from 20-120 ppm[1]. Average values in urban air from less than 1 to about 10 ppm.	CO is oxidized very slowly in the lower atmosphere. It is essentially chemically inert not reacting with other constituents of urban atmosphere to a significant degree.	a. Block of haemoglobin deprives the tissues of oxygen. Individuals suffering from cardio-respiratory disease are more sensitive. Psycho-physiological effects possible at low concentrations. b. Smoking is an important source of human exposure perhaps more significant than traffic exposure.	No effects on higher plant life at concentrations below 100 ppm (1-3 weeks exposure).	a. Several natural sources geophysical and biological identified but their contribution to the global balance of CO estimated to be small. b. Small amounts produced in fires and engine use as a by-product of hydrocarbons.
Sulphur dioxide (SO_2)	Energy and heat production from sulphur containing fuel. Industrial processes. Estimated global emission about 1.5×10^{11} kg/year	Air (water) (local and regional)	Annual averages in polluted urban areas up to 0.1-0.15 ppm.	a. Reducing type of air pollutant mainly formed by thermal oxidation of sulphur present in the fuel or sulphur-bearing ore. b. Atmospheric oxidation to SO_3 results in the formation of sulfuric acid mist and sulfates. c. Absorption and chemical reactions with suspended particles.	In combination with air borne particles (smoke) aggravates existing respiratory diseases and contributes to their development.	a. Chronic plant injury (0.03 ppm, annual average); susceptible species affected at 0.3 ppm for 8 hours; sulfuric acid mist produces leaf damage at 0.1 mg/m³. b. Reduced visibility (sulfuric acid mist and sulfates). c. Deterioration of materials, increased corrosion rate (largely due to sulfuric acid). d. Acidification of lakes and soils.	Natural sources such as volcanic gases contribute about 2% of the total SO_2 in the atmosphere. Global balance.
Airborne particles	Fuel combustion for heating and energy production, industrial processes, solid waste incineration, motor vehicles and other transport. Agriculture and forestry burning. Estimated global smoke emission, about 2×10^{10} kg/year.	Air (local, regional and global)	Annual averages in urban areas 40-400 $\mu g/m^3$	Chemically a most diverse class of substances. Because of their physical behaviour related to particle size (surface and optical properties, action) usually grouped together.	Synergistic effects with gaseous pollutants such as SO_2; possible toxic effects depend on chemical composition (e.g. lead, asbestos).	a. Reduction of direct sunlight and visibility; increased cloudiness and frequency of fogs; (these phenomena considerably affect amenity). b. Damage to materials, and soiling. c. Possible reduction of earth's temperature (long-range effect).	Natural sources dust storms and desert winds; volcanic eruptions, evaporation of sea spray (sea-salt). Stratospheric particles from meteoric origin.

Taken from: United Nations Conference On The Human Environment, Identification And Control Of Broad International Significance, A, CONF.48/8, January 7, 1972 pp. 10-17.

POLLUTANT	PRINCIPAL MAN-MADE SOURCES	DISTRIBUTION IN THE ENVIRONMENT	APPROXIMATE LEVELS	RELEVANT CHEMISTRY AND ENVIRONMENTAL INTERACTIONS	EFFECTS ON MAN'S HEALTH	EFFECTS ON THE ENVIRONMENT	REMARKS
Oxides of nitrogen (NO_x)	Oxidation of atmospheric nitrogen at high temperature (internal combustion engines, furnaces, incinerators, industrial processes; forest fires. Estimated global emission from combustion sources including petroleum refining, about 5.3×10^{10} kg/year.	Air (local and regional)	Usually less than 0.1 ppm; in heavy traffic up to 1 ppm. Marked diurnal patterns.	NO_x represents the sum of NO and NO_2. NO is the major oxide present in combustion emissions. Photochemical oxidation of NO in the presence of hydrocarbons produces irritants like peroxyacylnitrates.	Little information available at ambient concentrations; possible increase in acute respiratory infection and bronchitis morbidity in new-born children.	a. Brown haze in city air. b. Levels which cause acute injury to plants are above those normally found in the atmosphere. Localized destruction of forests near large industrial sources. c. Damage to materials.	
Volatile hydrocarbons and their products	Partial combustion of carbonaceous fuels (motor vehicles, stationary fuel combustion); industrial processes; solid waste disposal; solvents; forest fires.	Air (local and regional)	In highly polluted areas, maximum 1-hour values up to 10 ppm (as carbon)	Unreacted and partially oxidized products from the original fuel and substances formed by bond-rupture and subsequent re-synthesis. Reactive compounds such as alkenes play an important part in formation of oxidizing type of pollution.	Most of the effects are caused by compounds derived from atmospheric reactions of hydrocarbons, their derivatives and other substances (e.g. NO_x). Some oxidation products are eye irritants (acrolein, aldehydes).	a. Some compounds, e.g. ethylene, are very phytotoxic (sensitive plants are injured at 0.005 ppm). b. Reduced visibility due to aerosol particles, particularly as a consequence of atmospheric reactions. c. May produce unpleasant odours and affect amenity.	This group comprises hydrocarbons which appear in the atmosphere in vapour phase. Polycyclic aromatic hydrocarbons are not included.
Oxidants including ozone	Emissions from motor vehicles. Photochemical reactions of oxides of nitrogen and reactive hydrocarbons.	Air (local)	In highly polluted areas up to 0.15 ppm (8-hour average); strong diurnal and seasonal variations.	Secondary air pollutants produced by photochemical reactions of oxides of nitrogen with hydrocarbons. Oxidizing type of air pollution. A complex mixture of gaseous pollutants and aerosols (O_3, NO_2, peroxyacyl nitrates (PAN), free radicals, aldehydes ketones polymerised hydrocarbons etc.).	a. Eye irritation b. Possibly associated with asthmatic attacks. c. Impaired pulmonary function in diseased persons.	a. PAN injures sensitive plants such as tobacco, tomato at levels 0.01-01. ppm (1-8 hours exposure). b. Ozone considered one of the most damaging air pollutants for plants. c. Damage to materials, particularly rubber, textiles and metals. d. Pronounced reduction in visibility. e. Affect amenity.	Ozone is a natural and essential constituent of the upper atmosphere (few ppm).
Fluorides	Industrial processes (production of aluminium, steel, phosphate fertilizers, fluorinated hydrocarbons, brick-making). Combustion of coal. Industrial liquid wastes and agricultural run-off.	Air (local) water, soil, food	a. Average concentrations reported for a number of cities (USA) varied from about 0.001-0.02 ppm. b. Natural waters - very variable, range 0-20 mg/l. c. Food - very variable range 0.1-90 mg/kg.	Fluoride ion is an inhibitor for a number of enzymes.	Beneficial in small concentrations e.g. 1 mg/l in drinking water decreases incidence of dental decay. At larger levels (daily intake 2-8 mg) mottling of teeth; at still higher levels possible skeletal damage.	a. Fluorosis in grazing animals. b. Toxicity to fish varies widely depending on species. c. Injury to vegetation at concentrations of 0.002 ppm in air. d. Corrosion of metals, attack a wide range of building materials.	

POLLUTANT	PRINCIPAL MAN-MADE SOURCES	DISTRIBUTION IN THE ENVIRONMENT	APPROXIMATE LEVELS	RELEVANT CHEMISTRY AND ENVIRONMENTAL INTERACTIONS	EFFECTS ON MAN'S HEALTH	EFFECTS ON THE ENVIRONMENT	REMARKS
Odourous air pollutants	Industrial processes. Fuel combustion. Processing of animal products. Improper disposal of liquid and solid wastes.	Air (local)	Very variable. Odour thresholds range from as low as 1 part in 10^{17} parts of air for some compounds.	Odourous substances are often associated with incomplete oxidation of organic substances. Examples of common odorous compounds are: hydrogen sulfide, mercaptants, amines.	Objective evaluation is difficult due to incomplete knowledge of olfactory processes. Annoyance effects may interfere with everyday activities. No effect of odour per se is known to cause specific organic disease.	Marked interference with amenity.	Some odorous substances are highly toxic to man (e.g. H_2S) but their toxic effects are not necessarily related to the perceived odours.
Mercury (Hg)	Chlor-alkali plants. Mercurial catalysts Pulp and paper industry (slimicides). Seed treatment. Burning of fossil fuels. Mining and refining processes. Medical and research laboratories.	Food, fresh water and marine environment, soil, air (local, regional and global)	a. Air ~0.001-0.050 $\mu g/m^3$ b. Fresh waters ~ 0.01-0.1 $\mu g/l$ c. Sea water ~0.1 $\mu g/l$ d. Food, variable up to 0.05 mg/kg; however some fish from polluted areas may contain up to 1 mg/kg and more	a. Microbial conversion of inorganic Hg and some Hg-containing organic compounds to methyl mercury. b. Build-up in food chains particularly in fresh water and marine organisms.	a. Cumulative poison affecting nervous system (particularly methyl mercury) b. Epidemic outbreak of methyl mercury poisoning following ingestion of polluted shellfish and fish with fatal cases and congenital (fetal) disease (Minamata Disease in Japan)	a. Deaths in birds eating dressed seed (Sweden) b. Possible reproductive failures and population declines in predatory birds. c. Effects on aquatic vertebrates, including fish, and on phyto-plankton poorly understood.	a. Mercury in the ocean is largely of natural origin. Man's activities seem to have contributed only 1/1000 to 1/100 of the total amount. b. Compounds teratogenic in some experimental animals.
Lead (Pb)	Anti-knock ingredients of motor fuels. Lead smelting. Chemical industry. Pesticides. Burning of fossil fuels. Lead paints, glazes and enamels.	Air, water and food (local, regional and global)	a. Air - 1.3 $\mu g/m^3$ in polluted urban areas. In heavy traffic 14-25 $\mu g/m^3$. b. Fresh water - up to 0.14 mg/l c. Sea water - 0.01-0.3 $\mu g/l$ d. Food - generally 0.08 - 0.3 mg/kg.	a. Airborne Pb appears as aerosol, also associated with carbon particles. b. Lead alkyls volatile and fat soluble. c. Build-up in oysters and other shellfish. d. Little known about environmental transformations.	a. Main source of intake is food. b. Affects enzymes and heme synthesis; can affect nervous system. c. Accumulates in bone and kidney with potential long term effects. d. No recorded poisoning from eating aquatic food products.	a. Ecological effects not well understood. b. Stored in marine sediments.	a. Lead poisoning in children from repeated ingestion of lead-containing paint chips from walls in old houses has been observed in USA, UK and elsewhere. b. Suggested ADI? for lead is 0.005 mg/kg. c. Tumorigenic to experimental animals, but not to man.
Cadmium (Cd)	Mining and metallurgy (lead, copper and zinc smelters). Chemical industry (alkaline accumulators, alloys, paints and plastics) Scrap metal treatment, electro-plating. Superphosphate fertilizers. Cd-containing pesticides.	Air, soil water (local) food.	a. Air - urban areas (yearly mean) ~0.02 $\mu g/m^3$ non-urban ~0.003 $\mu g/m^3$, industrial up to 0.6 $\mu g/m^3$ b. Fresh water - up to 10 $\mu g/l$. c. Sea-water ~0.02 $\mu g/l$ d. Soil - 1-50 mg/kg in polluted rice fields (Japan) e. Food - generally below 0.05 mg/kg (milk 0.1-0.4, oysters up to 8, rice 0.1-1)	a. Known to accumulate in certain marine animals. b. Little known about environmental transformations.	a. Main intake from food b. Possible association with the "Itai-itai" disease in Japan (damage of kidney and skeletal system) c. Possible etiological factor in cardio-vascular disease.	a. Lethal for fish at fractions of a ppm. b. Little known about other ecological effects.	a. Compounds teratogenic in some experimental animals. No data available for man.

POLLUTANT	PRINCIPAL MAN-MADE SOURCES	DISTRIBUTION IN THE ENVIRONMENT	APPROXIMATE LEVELS	RELEVANT CHEMISTRY AND ENVIRONMENTAL INTERACTIONS	EFFECTS ON MAN'S HEALTH	EFFECTS ON THE ENVIRONMENT	REMARKS
Phosphates	Sewage. Agricultural run-off. Detergent "builders"	Fresh water and marine environment (local, regional)	Fresh waters - 0.3-1 mg/l (as P)		No recorded effects at environmental levels.	In excessive amounts considered a major factor in the process of eutrophication resulting in excessive growth of aquatic plants, depletion of oxygen, loss of fish and general degradation of water quality.	a. Essential nutrients for plants and normal constituents of man's and animal's food. b. Eutrofication is a natural process accelerated by man's activities.
Nitrates and nitrites	Sewage. Fossil fuel burning. Nitrate fertilisers. Industry.	Fresh water and marine environment, food (local and regional)	a. Fresh water - usually less than 5 mg/l but occasionally in excess of 100 mg/l. b. Food - very variable up to a few thousand ppm in some vegetables; in smoked meat up to 500-900 mg/kg (as NO_3) Concentrations of nitrites much smaller.	Nitrates reduced to nitrites and ammonia by intestinal microflora; nitrites are essential precursors in the synthesis of nitrosamines.	Nitrites in food and water may cause infantile methaemoglobinaemia.	In excessive amounts considered a major factor in the process of eutrophication of waters.	Nitrates are essential plant nutrients also used as food additives.
Alkyl sulfonates (AS)	Detergents in sewage and industrial wastes.	Fresh water and marine environment (local)	In polluted rivers of the order of 0.1-0.5 mg/l (expressed as methylene blue active substances).	Surface active agents, basic components of synthetic detergents. Alkyl benzene sulfonate (ABS) is stable and resistant to biodegradations. Linear alkyl sulfonates (LAS) show much better biodegradability.	Very low toxicity to man.	Discharge of detergent residues containing ABS results in foaming of receiving waters and interference with sewage treatment processes; conversion from "hard" ABS to "soft" detergents (LAS) reduced this problem.	
Chlorinated hydrocarbon (organo-chlorine) pesticides	Application in agriculture and public health. Industrial wastes (e.g. pesticide manufacture, wool and carpet manufacture.)	Soil, food, water, including marine environment, air (local, regional, global)	DDT and related compounds[4]: air - 0.1-400 ng/m^3 (London 10 ng/m^3) surface waters: 0.6-100 ng/l. rain water: 7-70 ng/l soil (arable): 0.1-5 mg/kg. food (whole diet): 0.03 mg/kg birds eggs: 0.15-30 mg/kg.	Include a variety of compounds such as DDT, dieldrin, aldrin, gamma-BHC. a. Biochemical degradation slow for most compounds. b. Soluble in fats c. Biological accumulation in aquatic food chains (concentration factor 100 to several thousand) d. Inducers of microsomal enzyme activity at low levels.	a. Approximate annual intake of general population 10-20 mg DDT mainly from food. b. General population body burden 10-20 mg/kg. Up to 40 times greater body burdens reported in occupationally exposed groups with no detectable adverse effect to individuals.*	a. Very toxic to crustaceans at extremely low concentration. b. Progressive accumulation in fish can cause disturbances in behaviour and failure of their embryos to hatch. c. DDT regarded as a significant hazard to some predatory birds which can accumulate residues to high concentrations (inability of eggs to hatch - thinning of egg shell).	LC_{50}^{96} values (mg/kg): DDT - 0.005 Heptachlor - 0.0024 Aldrin - 0.0021 Dieldrin - 0.0021

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Poly-chlorinated biphenyls (PCB)	Electrical industry; plastics industry, lubricants, industrial effluents and sewage, uncontrolled disposal (including incineration) of PCB containing products.	Water, including marine environment (local, regional and global)	Generally ppt range. Much higher levels (of the order of 10-100 ppm and more) found in tissues of some fish, seals and birds.	a. A large number of isomers, generally behave similarly to chlorinated hydrocarbon (organo chlorine) insecticides, resistant to oxidation and hydrolysis. b. Enzyme inducers at very low concentrations.	a. No known ill effects on man associated with exposure to PCB's at levels now found in the environment. b. Heavy and prolonged (occupational) exposure may produce skin lesions and liver damage. c. Possible association with mass poisoning in Japan (ingestion of rice oil contaminated with PCB's).	a. Although fairly high levels reported in shellfish and fish, no damage to marine life observed. b. High concentrations in liver of some birds. Possible cause of excessive deaths. Appear to disrupt the pattern of normal breeding behaviour and cause thin-shelled eggs. c. Other ecological effects not well understood.	a. Widespread environmental pollution by PCB's appreciated only recently because of difficulties in detection and analysis.
Asbestos	Mining operations, fibre production from the ore. Manufacture of brake linings and insulated pipes (asbestos-cement industry). Abrasion of brake linings in motor vehicles. Asbestos lined water pipes, asbestos filters.	Air and water (local, but widespread)	Estimated concentration in the vicinity of heavily travelled streets, 600-6000 particles/m^3; 3000-34000 $\mu g/m^3$ in the air near asbestos manufacturing plants. Airborne asbestos detected up to 80 km from industrial sources. Most natural waters contain traces of asbestos.	a. Asbestos is a broad term embracing several fibrous minerals. Chrysotile, a hydrated magnesium silicate, is the most common form of asbestos.	a. A possible factor in the incidence of lung disease along with other air pollutants and smoking. b. [illegible]y and long exposure (occupational) may cause specific chronic lung disease. c. Inhalation of asbestos has also been associated with mesotheliomas (a rare form of cancer).	a. Animal asbestosis recorded but rare. b. No reported effects on plants.	
Mycotoxins	Prepared food for man and feed for animals	Peanuts, beans and corn are principal food products contaminated with aflatoxins.	Aflatoxins: 0.1-1 ppm found in about 50% of food samples in Uganda and Thailand.	Aflatoxins are metabolic products of Aspergillus flavus. Chemical structure identified (e.g. aflatoxin B_1, B_2, G_1, G_2). Mycotoxins are produced also by other moulds (e.g. Penicillium islandicum).	Suspect to produce liver injury and cancer.	Known to kill ducks, turkeys and fish.	Very toxic but can be chemically monitored and controlled.
Polycyclic aromatic hydro-carbons (PAH)	Combustion of organic materials. Exhausts from gasoline and diesel engines. Atmospheric soot, cigarette smoke. Wastes from gas-works, refineries, chemical industry.	Air, water, food (local and regional)	Information incomplete. Data below refer mainly to benzo (a) pyrene. Air: 0.01-100 $\mu g/1000m^3$ (large local and seasonal variations). Surface water: 0.03-0.2 $\mu g/l$. Marine plankton: up to 400 $\mu g/kg$. Soil: 0-400 $\mu g/kg$ Smoked meat and fish: up to 50 $\mu g/kg$. Cigarette smoke: about 15 μg/1000 cigarettes.	Include a variety of chemical compounds such as benzo (a) pyrene (BP), dibenzo (a,i) pyrene, dibenzo (a,h) acridine.	The evidence that occupational exposure to mixtures of PAH (coal tar, petroleum products) causes cancer in man is conclusive. However the role of individual chemical compounds is not clear. For other types of environmental exposure, evidence is suggestive but not conclusive.	Information not available	

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Oil	Shipping accidents Run-off from transport wastes Polluted land drainage Refineries Offshore oil production	Fresh water, sea and land (local and regional)	Not applicable	Complex mixture of hydrocarbons. Forms surface films on water. In temperate and tropical zones biodegradable and oxidized under the action of light.	No direct effects observed from environmental exposure other than occupational.	a. Oil films greatly reduce uptake of oxygen by water. b. May cause mass death of sea birds. c. Generally low toxicity to marine life (not nearly as toxic as detergents used to disperse oil spillages). In estuaries and bays more toxic fractions together with oxygen depletion may produce more marked mortality of some species.	
Degradable organic matter	Sewage Garbage Industrial wastes Agricultural wastes	Fresh water and marine environment, land and soil (local)	In terms of biochemical oxygen demand (BOD) levels range from 1 mg/l in natural waters to 300-500 mg/l in untreated domestic sewage.	A complex mixture of carbohydrates, proteins, fats and oils, and other organic compounds.	No direct effect per se. Degradable organic matter in sewage may be associated with pathogenic organisms such as causative agents of water-borne diseases.	Major pollutant of fresh water bodies and coastal waters. Consumes dissolved oxygen. If present in excessive amounts damages aquatic life by oxygen depletion. High nutrient content may contribute to the process of eutrophication. May cause serious amenity problem affecting recreational uses of water.	
Solid wastes	Domestic, municipal, commercial, industrial and agricultural activities; Urban solid waste production approximately 500 kg per capita annually.	Land, fresh water and marine environment (local)	Not applicable	Contain degradable organic matter, paper, cardboard, metals, plastics, glass, etc. Industrial refuse may contain highly toxic materials.	Provides favourable conditions for infestation with rodents and flies and other disease vectors.	A major pollution problem with significant economic implications. Soil pollution and land degradation. Water pollution from dumping and run-off. Some disposal practices such as incineration cause local air pollution problems.	
Pathogenic organisms	Human and animal excreta (sewage, agricultural run-off etc.) Contaminated food and water.	Fresh water and marine environment, soil, (air)	Not applicable	Include a large variety of pathogenic bacteria, viruses and parasites responsible for food and water-borne diseases and diseases transmitted through soil contact	Transmission of communicable diseases such as cholera, bacillary dysentery, typhoid fever, bacterial food poisoning, amoebic dysentery, infective hepatitis. Major problem in a large part of the world.	May be responsible for diseases in livestock and wild life.	

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Ionizing radiation (including radio-nuclides)	Medical uses. Weapon production and testing. Nuclear power production. Uses of radio-isotopes and radiation sources in industry and research.	Air, fresh water and marine environment, land and soil. (Local, regional and global)	Genetic doses: Natural sources - 100 mrad/year. Medical applications - 6-60 mrad/year. Weapons testing: total doses to be received in the northern temperate zone by year 2000 - 110 mrads. Nuclear power production: current world-wide doses much smaller than 1 mrad/year.	Behaviour in the environment depends on chemical properties of radionuclides. Some can be strongly concentrated in aquatic food chains depending upon the organisms and nuclide species.	Acute somatic effects occur at doses above 100 rads. Long-term somatic effects (essentially induction of malignancies) believed to occur with frequency directly related to dose even at the lowest doses. Genetic effects are induced with frequency directly related to dose even at the lowest doses and may manifest themselves in the descendants of irradiated people, sometimes generations later.	No effects on the environment have been reported at current levels of contamination.	Radiation protection standards designed to protect human health have been accepted internationally.
Non-ionizing radiation	A variety of electronic devices such as microwave ovens, lasers, medical diathermy equipment, high power radio and radar transmitters.	Not applicable	Information inadequate	Non-ionizing portion of the electromagnetic spectrum covers at least 12 decades of energy and includes entirely different phenomena, interactions and biological effects from the ionizing region.	Microwaves: Lens of the eye is the critical target organ at about 3000 MHz (range of frequencies more commonly used in industrial, domestic and telecommunications applications). Lasers: Critical organs - eye and skin. Levels producing visible lesions depend on type of laser and are of the order of 0.1-1 joule/cm^2 for the eye. Little known about possible cumulative effects of low level exposure.	Information not available.	
Heat	Fossil-fuelled and nuclear power stations. Large urban areas.	Water, air (local)	a. "Thermal pollution" may locally increase the temperature of streams and lakes several degrees C. b. Cities may have a temperature 0.5-0.9°C higher than the surrounding countryside. Effect is more marked in winter months.	Increase of temperature in water increases reaction rate of chemical and biochemical process.	No direct effects related to thermal pollution of water.	Thermal pollution of water increases metabolic activity of aquatic organisms and may render estuaries and other waterways unsuitable for commercial species of fish and shellfish. b. "Thermal mountain effect" in cities (which raises the air to colder levels) aids the precipitation process.	At the present stage of technology nuclear power stations cause up to 50% more thermal water pollution than fossil fuelled stations per unit of power.

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Noise	Transportation - especially aircraft and motor vehicles. Industry Building construction Occupational and domestic sources	Air (local)	Typical urban background 60-80 decibels by day and 50-70 decibels by night	-	a. Subjective effects include annoyance, interference with speech, sleep, learning and task performance b. Objective effects may be immediate (e.g. temporary learning threshold shift) or cumulative (e.g. sustained sleep interference). Very long exposure may cause premature age-induced hearing loss. c. Knowledge of effects at low exposure inadequate.	May affect domestic animals and livestock similarly to man.	

1. ppm (parts per million by volume) multiplied by $\frac{\text{molecular weight} \times 10^6}{22400}$ yields micrograms of substance per cubic metre ($\mu g/m^3$) of air at standard conditions.

2. ADI (acceptable daily intake) of a substance is defined as "the daily intake which, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time" (FAO Agriculture Series, 1970, No.84, p.59; World Health Organization techn. Rep. Ser., 1970, 458 p.39). It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg). ADI for lead: World Health Organization techn. Rep. Ser. 1967, 373.

3. World Health Organization techn. Rep. Ser. 1970, 458, gives ADI value for a number of other pesticides.

4. 1 nanogram (ng) = 10^{-9} gram.

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* "Although there is definite evidence that, in mice, DDT in large doses increased the incidence of hepatomas, the significance of this finding in relation to man cannot be assessed as yet. In view of this, and in the light of the evidence available on the health of the individuals most heavily exposed to DDT, there is at present no sound reason to believe that the millions of people protected against vector-borne diseases are at tangible risk from their small exposure to DDT." (WHO (1971) Off.Rec. No. 190, p.178.)

This table was brought back from the United Nations Conference on the Human Environment (Stockholm, Sweden, June, 1972) by Milwaukee Public School representatives.

REFERENCES

The seven publications listed below are regarded as being pertinent and useful to any chemistry teacher involved with environmental chemistry. It is recognized that countless articles which deal with specific problems in environmental chemistry (such as lead poisoning or sulfur dioxide pollution) regularly appear and are available in numerous magazines and newsletters. However, deciding which of these articles is the most important reference on a given topic is truely a monumental task. The task is compounded by the fact that any articles chosen will be quickly superseded by the constant flow of new articles on the same topic. It is suggested that when further research on a topic is in order, the teacher or student should refer to the Reader's Guide to Periodic Literature for those articles which satisfy research needs.

The Authors

Cleaning Our Environment: The Chemical Basis for Action; American Chemical Society, 1969

Merck Index; The Merck Company, 1970

Handbook of Chemistry and Physics; Chemical Rubber Company, 1970

Chemistry; American Chemical Society, monthly publication.

Science News; Science Service, Inc., weekly publication.

The Science Teacher; National Science Teachers Association, monthly (September - May) publication.

The American Biology Teacher; National Association of Biology Teachers, monthly publication.